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The Use of GCCS in the Canadian Navy and its Relationship to C2IEDM

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The Canadian Forces is currently investigating numerous technologies that support data exchange. Within the Canadian navy, the Global Command and Control System (GCCS) represents an important system in use on all Canadian Frigates. The GCCS is also used extensively throughout the United States navy (USN) and thus the Canadian use also provides interoperability with the USN. Within the Canadian army, considerable resources and intellectual effort has been dedicated to the development of a semantics basis, shared among the NATO allies, called the Command and Control Information Exchange Data Model (C2IEDM). Since the Canadian forces also seek interoperability among its own services (air, navy and land), information exchange between the GCCS and C2IEDM-based systems like the Land Forces Command and Control Information System (LFC2IS) needs to be explored. Furthermore, this information exchange must take place in such a way to minimize semantic loss between systems. This report outlines both GCCS and C2IEDM and suggests a way forward for information exchange while maintaining semantic integrity. In the short term, it is suggested that C2IEDM be mapped to the messaging structure used by GCCS. In the long term, it would be advisable to have C2IEDM as an integrated ontological basis for the next generation of the supporting environment, namely the Net Centric Enterprise Services (NCES).

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Abstract

The Canadian Forces is currently investigating numerous technologies that support data exchange. Within the Canadian navy, the Global Command and Control System (GCCS) represents an important system in use on all Canadian Frigates. The GCCS is also used extensively throughout the United States navy (USN) and thus the Canadian use also provides interoperability with the USN. Within the Canadian army, considerable resources and intellectual effort has been dedicated to the development of a semantics basis, shared among the NATO allies, called the Command and Control Information Exchange Data Model (C2IEDM). Since the Canadian forces also seek interoperability among its own services (air, navy and land), information exchange between the GCCS and C2IEDM-based systems like the Land Forces Command and Control Information System (LFC2IS) needs to be explored. Furthermore, this information exchange must take place in such a way to minimize semantic loss between systems. This report outlines both GCCS and C2IEDM and suggests a way forward for information exchange while maintaining semantic integrity. In the short term, it is suggested that C2IEDM be mapped to the messaging structure used by GCCS. In the long term, it would be advisable to have C2IEDM as an integrated ontological basis for the next generation of the supporting environment, namely the Net Centric Enterprise Services (NCES).

Résumé

Les forces canadiennes étudient présentement plusieurs technologies afin de supporter l’échange de données. Dans la marine canadienne, le Global Command and Control System (GCCS) constitue un important système en utilisation sur toutes les frégates canadienne. GCCS est aussi utilisé de façon extensive dans toute la marine américaine ce qui permet un interfonctionnement systémique de facto. L’armée canadienne pour sa part a mis beaucoup d’efforts pour développer la base sémantique appelée Command and Control Information Exchange Data Model (C2IEDM), partagée parmi les alliés de l’OTAN. Comme les forces canadiennes visent aussi l’interfonctionnement entre ses propres services (air, mer, terre), l’échange d’information entre les systèmes respectifs supportés par ces environnements doit être étudié. De plus, cet échange d’information doit être supporté de telle façon à minimiser une perte sémantique qui peut survenir dans ce genre d’échange. Ce rapport décrit brièvement GCCS et C2IEDM et suggère un mécanisme pour supporter l’échange d’information tout en maintenant l’intégrité sémantique de l’information échangée. Il est suggéré à court terme qu’une correspondance de données soit faite entre C2IEDM et la messagerie structurée qu’utilise GCCS. À plus long terme, on suggère que C2IEDM soit intégré totalement comme base sémantique dans l’architecture évolutive de GCCS, soit le Network-Centric Enterprise Services (NCES).

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Executive summary

Introduction

The Canadian navy needs to explore integration avenues with both the Unites States (US) navy (USN) and the Canadian army. Interoperability with the USN is a necessity for the Canadian navy, but any Canadian joint operations must also allow navy-army information exchange. This document outlines the navy Global Command and Control System (GCCS) and the army ontological basis called the Command and Control Information Exchange Data Model (C2IEDM) and provides a way forward for combining data from these two systems.

The Canadian navy is currently using GCCS and its supporting systems architecture, the US Defense Information Infrastructure (DII) Common Operating Environment (COE), as part of its command and control system onboard Canadian Frigates. The formatted messaging structure Over-The-Horizon Targeting Gold (OTH-T-GOLD) is used by GCCS for message passing with other GCCS nodes.

The US Navy also uses the COE GCCS. The US Department of Defense is researching the next generation of the COE under a project called Net Centric Enterprise Services (NCES).

Under the Multilateral Interoperability Programme (MIP), the Canadian army is one member organisation researching and developing the C2IEDM along with the other member nations. The C2IEDM along with its Information Exchange Mechanism (IEM) are intended to be the primary means to achieve systems interoperability between NATO nations. The Canadian implementation of C2IEDM is the Land Force Command and Control Information System (LFC2IS).

Principal Results

The quickest way to ensure systems interoperability between GCCS and the LFC2IS is to build interfaces between the OTH-T-GOLD messaging structure and the C2IEDM. An OTH-T-GOLD-C2IEDM interface is currently being built under the auspices of the Intelligence, Surveillance, Target Acquisition and Reconnaissance (ISTAR) Technology Demonstration (TD) led by DRDC Valcartier. While this solution is viable in the short term, studies tend to prove that this kind of mapping can only hold for a limited subset of semantic concepts, captured and shared by each system. This may still be enough if the exchange of information taking place supports the combined army-navy operational context.

In the longer term and for complete coverage of the domain semantics, the suggestion is to incorporate the C2IEDM as a structured information repository for the planned NCES. Indeed, the C2IEDM is recognized as a very mature solution, approaching an exhaustive ontological basis, a recognized necessity for supporting systems interoperability. This incorporation would allow the existing C2IEDM-based systems to appear as information providers, virtually making the NCES architecture completely interoperable with the NATO allies at the semantic level.

Significance of Results

In the short term, information exchange interface development between GCCS and LFC2IS (like demonstrated in the Atlantic Littoral ISR Experiment - ALIX) must be pursued and broadened to address the needs of the various army-navy operational contexts. For the Canadian navy, this avenue allows continued short-term interoperability with the USN thereby minimizing the cost of application development while maximizing data usage.

The longer-term solution provides the Canadian navy with a very reasonable approach to the exploitation of C2IEDM-based systems within a C2IEDM-enriched NCES vision. As such, NATO allies adopting the MIP solution will reach systems interoperability within the NCES vision as well.

Future Plans

DRDC Valcartier is currently working towards an update of the data mapping between the OTH-T-GOLD and the C2IEDM. There are also TD Projects at DRDC Atlantic that will examine the exchange and combining of data from multiple sources and platforms. All of these efforts are focused on advancing the Canadian Forces in the area of information sharing and exchange.

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Sommaire

Introduction

La marine canadienne se doit d'explorer les avenues d'intégration tant avec la marine américaine qu'avec l'armée de terre canadienne. L'interfonctionnement avec la marine américaine est une nécessité, et toutes les opérations jointes canadiennes doivent aussi permettre l'échange d'information entre les systèmes des forces de mer et de terre. Ce mémorandum technique décrit le système Global Command and Control System (GCCS) et la base ontologique de l'armée de terre appelée Command and Control Information Exchange Data Model (C2IEDM). Des solutions d'échange d'information entre GCCS et les systèmes basés sémantiquement sur le C2IEDM seront ensuite exposées.

La marine canadienne utilise présentement GCCS ainsi que son architecture de systèmes « US Defense Information Infrastructure Common Operating Environment » (DII COE) en tant que partie de son système de commandement et contrôle sur ses frégates. La spécification américaine de messagerie structurée Over-The-Horizon Targeting Gold est utilisée par GCCS pour transmettre et recevoir des messages entre nœuds GCCS.

La marine américaine utilise aussi DII COE GCCS. Le département de la défense américain travaille présentement à l'évolution du DII COE sous le projet « Net Centric Enterprise Services » (NCES).

En tant que membre du « Multilateral Interoperability Programme » (MIP), l'armée canadienne développe le C2IEDM en compagnie des autres nations membres. Le but du développement du C2IEDM ainsi que son mécanisme d'échange d'information « IEM » est de réaliser l'interfonctionnement sémantique entre les nations de l'OTAN. Le système de commandement et contrôle canadien basé sur l'implémentation nationale du C2IEDM est le Système d'Information de Commandement et Contrôle des Forces Terrestres (SICCFT).

Résultats Principaux

La façon la plus rapide de réaliser un interfonctionnement systémique entre GCCS et le Système d'Information de Commandement et Contrôle des Forces de Terre (SICCFT) est de construire des interfaces entre la structure de messagerie OTH-T-GOLD et C2IEDM. Un interface entre OTH-T-GOLD et C2IEDM a été construit et démontré lors de l'expérience ALIX en août 2004 comme preuve de concept. Solution viable à court terme, les études tendent à prouver que cette solution d'interfonctionnement se limite généralement à un sous-ensemble des concepts sémantiques compris dans chaque source d'information. Ceci peut toutefois représenter une solution suffisante

dans la mesure où les opérations jointes terre-mer sont supportées par ce contexte d'interfonctionnement.

À plus long terme et pour une couverture plus complète des domaines sémantiques, il est suggéré que le C2IEDM soit incorporé dans le NCES en tant qu'entrepôt d'information structurée. En effet, le C2IEDM est reconnu comme une solution mature, approchant les caractéristiques d'une base ontologique exhaustive, une condition requise pour supporter l'interfonctionnement systémique. Cette incorporation permettrait aux systèmes basés sur C2IEDM d'agir en tant que fournisseur d'information directement dans le paradigme de NCES. De plus, NCES deviendrait de facto interopérable avec les systèmes de l'OTAN au niveau sémantique de l'information.

Signification des résultats

À court terme, le développement d'interfaces entre les systèmes de la marine et de l'armée de terre (tel que démontré à l'expérience ALIX) doit continuer et être étendu pour adresser les besoins opérationnels terre-mer plus complexe. Pour la marine canadienne, cette voie permet de maintenir l'interfonctionnement avec la marine américaine, minimisant ainsi les coûts de développement tout en maximisant l'utilisation de l'information.

La solution à long terme fournit à la marine canadienne une avenue d'accès aux systèmes basés sur C2IEDM à travers la vision NCES. Il en est de même pour les systèmes de l'OTAN qui se baseront sur la solution MIP.

Projets futurs

RDDC Valcartier mets à jour présentement l'interface entre OTH-T-GOLD sous les activités du projet Intelligence, Surveillance, Target Acquisition and Reconnaissance Technology Demonstrator (ISTAR TD). Il existe également à RDDC Atlantique des projets de démonstration technologique qui étudient l'échange et la combinaison de données provenant de multiples sources et plates-formes. Ces efforts on pour but l'avancement des forces canadiennes dans le domaine de l'échange et partage de l'information.

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Table 1. Version 4.7 COE-component segments are grouped into 14 bundles. The bundles cover the functional requirements of the general environment. The names of these bundles are part of the COE Taxonomy. 6

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1. Introduction

In the past, system development has been focused on monolithic systems, addressing specific functional requirements. A typical scenario of development involves the identification of a system or process requiring improvements. The defined functional requirements then specify the modifications and design criteria. Then, the development proceeds based on the requirements, available resources, and existing infrastructure.

From a naval perspective, the traditional unit around which the development took place was typically a naval platform. The development would not necessarily create a system to be placed on a particular platform, but would in some way support the activities of the platform. In most cases, we may consider the platform[1] to be a naval ship.

Many of the developments to be deployed on a ship would address the command or tactical needs of the ship. Across a common class of ships, this often results in similar systems being deployed on a single class. In this way the interoperability of a particular class was realized. However, interoperability between different classes or indeed, different state navies, was often not reached.

In the Canadian navy, multiple ships working collectively for a common goal are termed a task group. A task group utilizes the expertise and systems available on all the platforms, thereby maximizing its collective effectiveness to meet the mission goal. However, groups of ships working in partnership may also be composed of multinational platforms. In either case, data exchange between the platforms is required to maintain a consistent view of the operational environment. Such data exchange may take many forms, such as a transfer via voice messaging, or data formats such as Over-The-Horizon Targeting Gold (OTH-T-GOLD) or Link 11.

However, information exchange through the use of message text formats such as OTH-T-GOLD, Allied Data Publication-3 (Adat-P3) and United States (US) Message Text Format (USMTF) suffers from the fact that the semantics conveyed are often not complete or worse, are overlapping. Therefore interoperability requirements, driven by the operational context, are not met. To compensate for this, unstructured information transferred via voice communications or through unstructured message exchange (e.g., GENTEXT, email, etc.) may be keyed into systems to complete the information exchange.

Furthermore, formats such as OTH-T-GOLD and Link 11 have been developed based on the data exchange requirements of the past. These formats met the needs of the command and control systems for which they were built. However, the task group or coalition environment in present day operations has different information requirements

[1] Platform may also refer to an air or subsurface asset.

(IRs) and Information Exchange Requirements (IERs). Multiple sensors, on multiple platforms, exchanging and fusing data, place additional requirements on the transfer. Formats, such as OTH-T-GOLD and Link 11, have not evolved to meet these current IRs and IERs. The formats do not cover all the semantics required to conduct coalition or joint operations of today.

Numerous single-system transfers use these message text formats. Here, single-system refers to two instances of the same system operating in two locations. For example, the Global Command and Control System (GCCS) in use in the Canadian Navy can use OTH-T-GOLD to transfer point-to-point data between two GCCS instances on two different ships. GCCS was developed by the US and is used extensively in the Canadian navy. Its use in Canada is an essential requirement for maintaining data interoperability with the US navy (USN).

Interoperability between national platforms or within a coalition has been an active area of military research. In the US, much of this effort falls under the term, Net Centric Warfare (NCW). In Canada, it has been suggested that NCW is too restrictive and ill-defined [1]. For example, the human or social dimension is not apparent in NCW literature. Some Canadian researchers are suggesting adoption of the term Network Enabled Operations (NEOps).

Some of the research conducted under the titles NCW or NEOps is examining architectures or models that will support data and information sharing. However, this type of research may be conducted along many different implementation pathways. This raises the question of whether or not there will be interoperability between pathways. This report will examine two interoperability pathways that are particularly applicable to the Canadian Forces (CF).

1.1 Outline

The following report provides very general information on two interoperability pathways being researched or used within the CF. The first pathway suggests a means to achieve systems interoperability by interconnecting systems through specific interfaces. The second pathway describes the approach where systems are designed to use a single shared semantic basis.

Sections 2 and 3 of this report describes the building blocks constituting the subjects of this study. Section 2 introduces the US Defense Information Infrastructure (DII) Common Operating Environment (COE) systems architecture, developed by the US Defense Information Systems Agency (DISA). The COE is an environment for collaborative software development and execution. One system operating in the COE environment is the GCCS, which is also briefly described. GCCS was also developed in the US, but is used by many allies including Canada. One method of GCCS data communication is the messaging format Over-The-Horizon Targeting Gold (OTH-T-GOLD). OTH-T-GOLD will also be briefly described.

Section 3 introduces an interoperability solution development by the Multilateral Interoperability Programme (MIP). Over the last two decades, MIP has been involved in the specification and development of the Command and Control Information Exchange Data Model (C2IEDM, soon to be renamed to Joint Consultation Command and Control Information Exchange Data Model, JC3IEDM, to reflect its move toward joint operations). The C2IEDM has a long development history, with the initial concept dating back to the mid 1980s and the Generic Hub data model.

Finally, the two interoperability approaches that serve to link the GCCS and C2IEDM will be proposed in Section 4. The approaches will be described as either short or medium-term solutions for the navy. These solutions will account for the planned development of the COE by the USN and for the planned use of the C2IEDM by the Canadian army.

2. The Common Operating Environment

The Defense Information Infrastructure (DII) Common Operating Environment (COE) was designed and built in the early 1980's, with the goal of eliminating incompatibility between US Department of Defense (DoD) systems. The COE is truly an environment in which other applications operate. As an environment, the COE provides the necessary base services for the higher-level applications.

One system operating in the COE environment is the GCCS. The GCCS was developed in the US and is used by many allies including Canada. The GCCS provides military support in areas such as force mobilization and deployment.

As with most military packages, the COE and GCCS are evolving both in terms of their technology and the conceptual ideas upon which they are based. In the next generation of development, the COE will evolve into a larger networked system, called Net Centric Enterprise Services (NCES). NCES is important because of the impact on the evolution of systems to the network paradigm and in particular on the potential impact on how applications and databases interact. The next generation of GCCS is the Joint Command and Control (JC2) system. JC2 will be one application running within the NCES.

2.1 COE Description

The COE can be viewed from various perspectives, with each perspective resulting in a slightly different description and understanding. Some view the COE from the perspective of functional areas [2] while other documentation [3] views it as a multi-faceted concept. The COE Integration and Runtime Specification [3] (I&RTS) describes the multi-faceted concept where the COE may be viewed as a system foundation, a reference implementation, an implementation strategy and as an architecture.

In the system foundation view [3], the COE should be considered a foundation for the construction of other systems. The COE itself is not a system, but rather is a collection of components. These components are combined is different combinations to build specific mission applications.

We may also view the COE as a reference implementation [3]. In this view, we consider the base components that make up the COE. These base components are the same for each implementation. Here we are ignoring differences in the binary executable files that result from platform specifics.

The COE may also be viewed as an implementation strategy [3]. The COE strategy is based on the compartmentalization of functions into well-defined components that form the COE. The strategy also includes the evolution of the component, where new functionality may be built into the component in such a way as to move the COE foundation forward. The strategy also considers legacy systems and how such systems may be integrated into the COE.

Finally, the COE may be viewed as an architecture [3] designed around the “plug and play” concept. The software modules constructed for this “plug-and-play” concept are called segments. Segments developed as part of the COE are referred to as COE-component segments. These segments must adhere to well-defined development specifications as described in the COE I&RTS [3]. These segments may be considered a functional software component that typically addresses a specific functional requirement. However, these requirements are for the general environment and are not related to specific applications.

These COE-component segments may also be conceptually bundled according to general functionality. One bundle represents the kernel services, providing control over COE administration, including utilities to manage and control the COE base system. In version 4.7 of the COE, there are a total of 203 COE-component segments in 14 bundles [4]. The 14 bundles are listed in Table 1.

Individual mission requirements are typically addressed through multiple segments. A common set of core segments (e.g., the Kernel) is combined with specific mission segments. Each mission requirement may utilize a different set of the COE-component segments, depending on the particular mission. For example, the mission requirement addressed by the Global Command and Control System – Maritime (GCCS-M) utilizes a particular set of COE-component segments that may be different from other mission requirements.

As well, an application such as GCCS-M will have developed segments that specifically contribute to the required functionality of the mission. These segments are referred to as mission-application segments. The mission-application segments also meet COE specifications but are not part of the COE proper.

Table 1. Version 4.7 COE-component segments are grouped into 14 bundles. The bundles cover the functional requirements of the general environment. The names of these bundles are part of the COE Taxonomy.

BUNDLE ABBREVIATION	BUNDLE DESCRIPTION
ALS	Alert Services
AS	Administrative Services
CMS	Configuration Management Services
COP	Common Operational Picture
DAS	Data Access Services
K	Kernel
MCGI = MCG&I	Mapping, Charting, Geodesy and Imagery
MMCS	Multimedia/Collaborative Services
MSG	Messaging
NMS	Network Management Services
OA	Office Automation
PS	Print Services
SDS	Software Development Services
SS	Security Services

2.2 Global Command and Control System

The GCCS was designed to address six mission areas for the DoD, namely operations, mobilization, deployment, employment, sustaining the mission and intelligence. As with many other systems, the unique challenges associated with military disciplines has resulted in GCCS development that is oriented towards the particular needs of the military community. For example, the GCCS-Army (GCCS-A) [5] is a command and control system that addresses specific army requirements. GCCS Top Secret (GCCS-T) [6] provides command and control capabilities in a top-secret environment. Similarly, GCCS-J (Joint) [7], GCCS-I3 (Integrated Imagery and Intelligence) and GCCS-M (Maritime) [8] provide specialized functionality. These specialized systems may collectively be considered the GCCS Family of Systems (FoS).

The GCCS-M system is of particular importance to the Canadian and US navies. GCCS-M supports navy-based ashore, floating and mobile/tactical environments. GCCS-M provides a technical solution for the display of information in a common operating picture (COP). GCCS-M is reported to integrate data from over 80 different command and control systems [9].

GCCS-M is one system within the GCCS FoS. It is important to note that current US plans call for all the systems to be brought together under the Joint Command and Control (JC2) system. Current budgets indicate that the GCCS-J will form the initial core of JC2 [10].

2.3 Over-The-Horizon Targeting Gold Message Format

As noted previously, GCCS-M is currently installed on the Canadian frigates. Part of the GCCS-M install is the Tactical Management System (TMS) [11]. The TMS segment provides the database management function for the tactical data.

A planned fit will result in the installation of GCCS-M I3, which is an assortment of selected functionality from GCCS-M and GCCS-I3. This combines some functionality from both the maritime and intelligence communities.

One functionality being included as part of the GCCS-M I3 install is the Modernized Integrated Database (MIDB). The MIDB is a repository for intelligence data and is used by American, Canadian and Australian navies. Links exist between numerous COE-component segments and the MIDB mission-application segments. Of particular interest, are the mission-application segments under the GCCS-I3 that support the manual fusion process and display of multi-source data. Some of these mission-application segments are now being incorporated into GCCS-M I3 install.

GCCS-M and GCCS-M I3 use the operational specification for OTH-T-GOLD formatted structured messages. Under this specification, the semantics of the exchangeable operational information is captured and standardized into “Message Text Formats” (MTFs). In effect, a MTF is a collection of semantically complete operational information. In turn, a MTF can be broken into sets that convey more atomically specific information (e.g., the POS set specifies a position). Again, each set can be broken into fields that pertain specifically to that set (e.g., “Latitude of center” is a field comprised in POS). If a specific field takes values in a ranged set, then the OTH-T-GOLD specification enumerates the range set.

2.4 Net Centric Enterprise Services

There are current plans to evolve the entire COE to address interoperability issues associated with a networked military. DISA plans call for the evolution of the COE via a program named Net Centric Enterprise Services (NCES) [12]. In many respects, NCES may be considered the next generation of the COE.

To understand the evolution of COE to NCES, one needs to appreciate the differences in the data handling methods. In the COE described above, the data exist and are accessible within the COE architecture. In this environment, segments have direct control over the creation and manipulation of the data within the various databases. The data exist within the environment and are accessible by applications operating within the environment. The data are not necessarily easily accessible by applications external to the COE.

The goal of NCES is to separate the data and applications from the environment. In the NCES, the data conceptually exist as a service that is independent of the application. These data services are also a component of the US Global Information Grid (GIG). NCES is intended to provide services in support of the GIG.

In terms of architecture, NCES is constructed from Core Enterprise Services (CES) and Communities-of-Interest (CIO) (Figure 1). CES provides services to the entire network. For example, CES will provide discovery services for the discovery of data and services over the network. There will also be services for the mediation of collected information and collaboration tools. CIO will be connected to the services via a communications backbone. COI will be organized around existing DoD communities [13].

Data may exist in either the CES or COI sections of the architecture shown in Figure 1. The discovery service would provide the mechanism to locate and access the required data service or application.

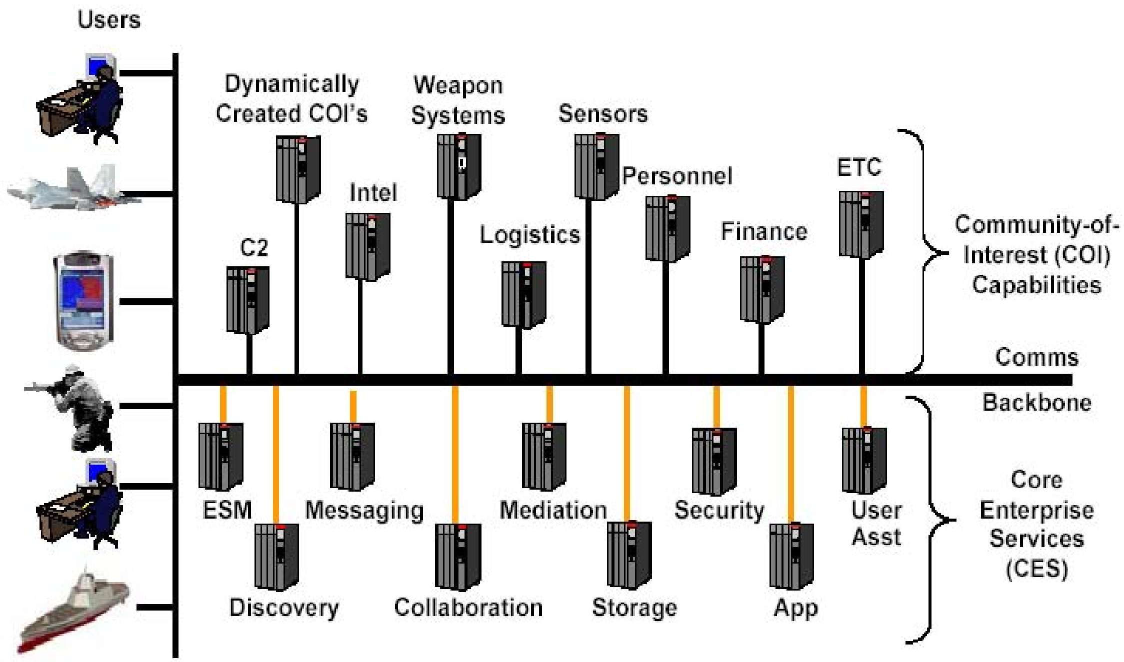

Figure 1. *The NCES is based on Core Enterprise Services (CES) providing essential services to numerous communities-of-interest (COI). Users connect to the communication backbone and thereby connect to the CES and CIOs. Reproduced from [13].*

3. C2IEDM

The Command and Control Information Exchange Data Model (C2IEDM) [14] is a development that originated in the Multilateral Interoperability Program (MIP) [15]. MIP is not a formal program, but rather is a voluntary activity of supporting nations. The aim of the MIP is "*to achieve international interoperability of Command and Control Information Systems (C2IS) at all levels from corps to battalion, or the lowest appropriate level, in order to support multinational (including NATO[2]), combined and joint operations and the advancement of digitization in the international arena*" [16].

MIP (and the former Army Tactical Command and Control Information System (ATCCIS) programme) have been involved in the specification and development of the C2IEDM for over two decades, with the initial concept dating back to the mid 1980s and the Generic Hub data model. C2IEDM will soon be renamed to the Joint Consultation Command and Control Information Exchange Data Model (JC3IEDM), to reflect its move toward joint operations.

The MIP solution consists of two main functional components: 1) the C2IEDM, and 2) the Information Exchange Mechanism (IEM). Both will be briefly described.

3.1 C2IEDM Description

The MIP committee approved the C2IEDM Edition 6 in November 2003. The data model specification and supporting documentation was made available on the MIP web site [15] in the spring of 2004. The C2IEDM is the natural evolution of the LC2IEDM (prefix L indicates Land), with additional tables for navy and air force specific information. There has also been additional work on clarifying some table descriptions and content to make a more generic structure.

When considering the C2IEDM, we must first recognize several important terms that relate the C2IEDM to the larger system. The C2IEDM is not a system but rather a structured set of semantic concepts and their relationships that pertain to an ontology definition (a semantic basis). The C2IEDM as a data model serves as the means to capture the military ontology necessary to conduct coalition operations. It consists of about 200 tables and supporting relationships. The main model concepts deal with objects that exist at described locations. The model allows the objects to have described capabilities, which leads to the objects conducting certain actions on targets. The objects may also operate in a certain context which may be defined by the reporting of associated objects, capabilities, actions, etc. or through the actions of the objects relative to described rules-of-engagement.

[2] NATO – North Atlantic Treaty Organization

3.2 Exchange Description

The second component of the MIP solution is the Information Exchange Mechanism. The IEM accounts for two types of exchange: The Message Exchange Mechanism (MEM) and the Data Exchange Mechanism (DEM).

3.2.1 The Message Exchange Mechanism

The Message Exchange Mechanism (MEM) [17] uses the Extended Simple Mail Transfer Protocol (ESMTP) to exchange Adat-P3 formatted messages. MIP maintained a set of these messages that capture key information within the C2IEDM. Although the MEM was meant to convey semantic information between MIP-compliant nodes it proved to be flawed for a number of reasons. First, the semantic integrity of these messages is very hard to ensure. This is because the Adat-P3 (as well as other message text formats like OTH-T-GOLD and USMTF) is merely a collection of military terms with no definitions or relationships. Second, the semantics of a message is given through the message structure (e.g., Situation Report, etc.) and its composition. The attributes that compose the messages often violate the normal forms[3] of data modeling, thus preventing the unambiguous representation of the information. Finally, the high-cost maintenance of this solution proves to be a major drawback as a number of MIP experimentations have shown. Since 2004, the MIP decided to use MEM only to convey writer-to-reader information, and to use the Data Exchange Mechanism to convey the C2IEDM structured information between MIP-complaint systems.

3.2.2 The Data Exchange Mechanism

The MIP Technical Interface Design Plan [17] details the DEM. Broadly, it consists of the replication of data between instances of the Command and Control database (C2DB, note that for clarity the database is being distinguished from the data model). Several MIP members, including the Canadian army, have an implementation of the automated replication mechanism (ARM) specification. The ARM is built on a replication database that consists of about 40 tables (Figure 2). These tables are used to coordinate the transport of data from one C2DB instance to another. In essence, the ARM database identifies nodes in the C2DB network, protocols between the nodes, data contracts between the nodes, and the actual data contained in the C2DB instance. In terms of the data, the ARM database holds information on the data value and the

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[3] Normalization is a design process that minimizes data redundancy and anomalies within a data structure [18].

table and column where that data value resides in the C2DB instance providing the data. Since the database to be replicated is an instantiation of the C2IEDM, information exchange between systems constitute semantically complete sets.

Implementing the DEM is not trivial. However, as compared to the MEM, the DEM constitutes an information exchange solution better suited for systems interoperability. This is because the DEM deals specifically with replication between C2DB instances. Thus, the DEM is capable of conveying the semantic meaning and relationships present within the data contained in the C2DB.

The ARM provides C2DB to C2DB communication, while other software provide direct links for placing and retrieving C2DB data. Software applications developed by DRDC Valcartier, such as OPERA, provide operational functionality out of the C2DB. Software developed by the US Naval Undersea Warfare Center (NUWC), called the Operational Context Exchange Service (OCXS, [19]), provides an eXtensible markup language (XML) based data entry method to the C2DB. A schematic of an OCXS message object placing data into the C2DB is shown in Figure 3.

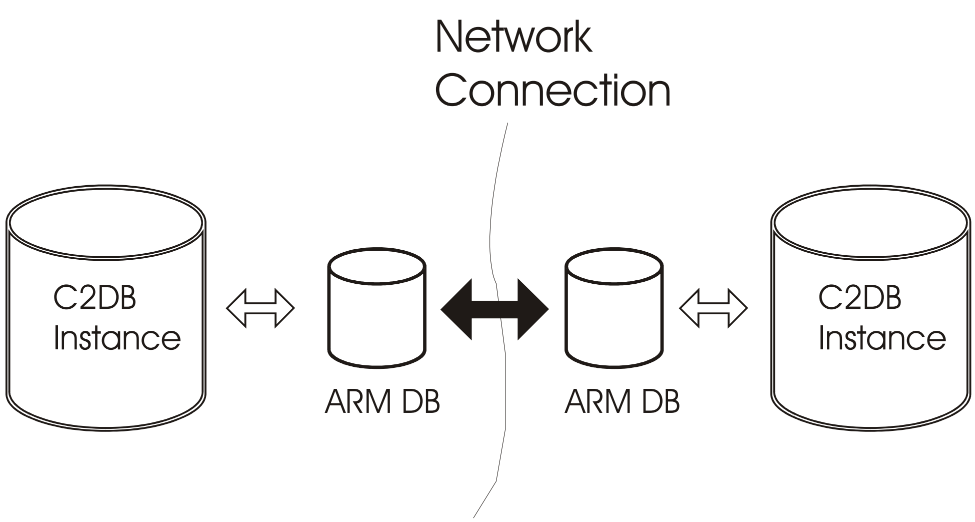

Figure 2. The ARM consists of a database specifically for managing the data replication between two C2DB instances. The ARM database consists of about 40 tables, while the C2DB consists of about 200 tables. Reproduced from [20].

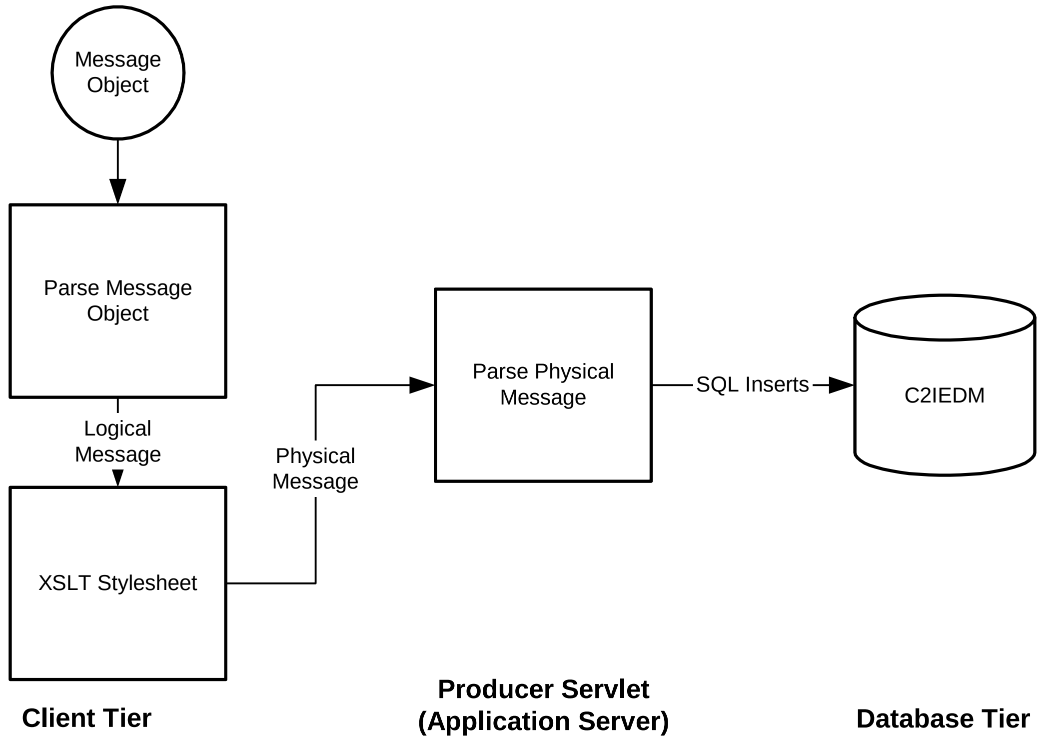

Figure 3. The OCXS uses input message objects in XML, to construct SQL input statements that are used to place data into the C2DB (shown here as C2IEDM). Reproduced from [21].

4. GCCS-M and the Navy

The background of the COE, GCCS-M and C2IEDM has been established in the preceding sections. We now outline the position of the Canadian navy with respect to these technologies and developments. Once the navy's position is established, we will explore potential development scenarios that satisfy the requirements of the CF in the future.

4.1 The Future of GCCS in the Canadian Navy

The Canadian navy has considerable expertise and developed knowledge regarding the COE, GCCS-M and supporting databases. The USN also has considerable investment in all of these technologies. As well, the USN has development plans extending to 2010 to utilize GCCS-M as the central component in the development of the Common Underwater Picture (CUP) [22]. A US program supporting anti-submarine warfare (ASW) operations will concentrate on the development of decision support and collaboration tools for the specific purpose of providing a shared awareness and understanding of the underwater scene. GCCS-M is the intended host of the development. The plan also calls for the eventual host being JC2. The estimated funding required for this development is $57 million USD over 5 years.

The Canadian Navy recognises the continued support that GCCS-M is obtaining from their US counterpart. A recent memorandum from Canadian Vice Admiral R.D. Buck clearly states the Canadian Navy's need for compatibility with US COE and future NCES developments. As stated, "*adoption of any non-NCES approach is unacceptable to the [Canadian] navy*" [23].

There are two primary reasons for this strong position. First, a non-NCES approach would distance the Canadian navy from full interoperability with the US navy. Second, it would place additional resource commitments on the Canadian navy, to finance the necessary systems and development to regain interoperability with the USN. Both would lead to reduced capabilities for the Canadian navy.

The memorandum clarifies the navy position on the future Canadian maritime operating environment. However, the need for a joint command and control data model is also recognized, provided the support comes with the necessary resources for the maritime portion and that it builds on the existing initiatives with the USN [23].

4.2 Data Transfer Pathway

Based on the above information, it is reasonable to expect the continued use of GCCS-M in the Canadian navy. However, the Canadian army has devoted considerable resources to the research and development of the C2IEDM. The data model and system that support the model have now entered the demonstration phase. One recent demonstration showed data transfer between national systems involving Canadian, US and Portuguese implementations [24].

The apparently divergent positions of the USN and the Canadian army, places the Canadian navy in a middle position. The navy needs to explore methods of maintaining data flow with the Canadian army, while remaining interoperable with the USN. Thus, we need to determine if there exists a reasonable and feasible data transfer pathway between the GCCS-M and C2IEDM systems.

To explore possible pathways, we should first consider the existing GCCS-M software and its use. The existing applications, such as those that support data fusion[4] under GCCS-I3, provide benefit because they utilize data available via existing data structures. For example, the MIDB structure provides data to the GCCS-I3 application, thereby utilizing the collected intelligence data. The navy are familiar with these applications and would likely support a progression that allows the continued use of such applications.

For the continued use of these applications, one possible solution is to incorporate the C2IEDM into the COE, effectively producing a C2IEDM COE segment. This would provide the entire C2IEDM data source to all COE applications[5]. However, the applications presently existing within the COE would not be able to utilize the data source without modification to the application. This is because the application would not be working in the same semantic space as the C2IEDM segment. Alternately, the C2IEDM segment may include a mapping application to exchange data with an existing COE segment (e.g., MIDB or TMS) that is utilized by other applications. This would effectively provide a bridge between the C2IEDM and application segments. However, the full semantic data space offered by C2IEDM would not be utilized by the application, because only those data that could be stored in the intermediate segment would be available to the application. This condition is known as *semantic loss* [26].

This type of mapping application or bridging has potential benefits in the medium term. The development would provide an increased data sharing capability between the Canadian army and navy. However, the level of effort required for the mapping may be considerable. As well, it should be recognized that any resources spent on

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[4] The data fusion capabilities in GCCS-I3 may be described as manual Level 1 fusion [25]. This means the operator is responsible for associating observations from external sources with existing tracks within the GCCS.

[5] Application is used to describe one or more mission-application segments, which combine to address a particular functionality.

such a development are not contributing to the longer term USN NCES vision. In the NCES future, the data sources will be autonomous services in the enterprise. As such, data sources will not be linked to particular applications, but rather to the enterprise. In turn, enterprise applications are available to utilize the data services.

To meet immediate needs, a short-term development solution is sought that allows the GCCS-M and supporting applications to utilize data from the C2IEDM, but requires minimal development effort. One potential avenue that satisfies these requirements involves the mapping of the C2IEDM structure to the GCCS messaging structure, OTH-T-GOLD (Figure 4). This avenue would allow the transfer of unit positional information from a C2DB to either a GCCS-M or GCCS-M I3 system. This type of mapping is part of the C2IEDM effort underway in DRDC Valcartier. Also, DRDC Valcartier has produced an interface between OTH-T-GOLD and the C2IEDM, thus giving access to Tactical Management System (TMS) data. This was demonstrated in the 2004 Atlantic Littoral Intelligence, Surveillance and Reconnaissance (ISR) Experiment (ALIX) experiment and will likely be documented in the final report.

4.3 Other US Integration Activities

As the development of NCES comes to fruition, the potential integration of a data source such as C2IEDM becomes more likely. One could envisage the C2IEDM being one of the many data services available on the NCES (Figure 4). In this case, applications that have been built to support the NCES then become accessible to the C2IEDM thus allowing data flow into and out of the C2IEDM data source.

The NCES vision is currently being explored in the US in the form of initiatives that directly contribute to interoperability solutions involving GCCS-M. The eXtensible Tactical C4I[6] Framework (XTCF) is one such US initiative. This project, established under the Office of Naval Research (ONR), may be considered a prototype implementation of NCES.

[6] C4I – Command & Control, Communications, Computers and Intelligence

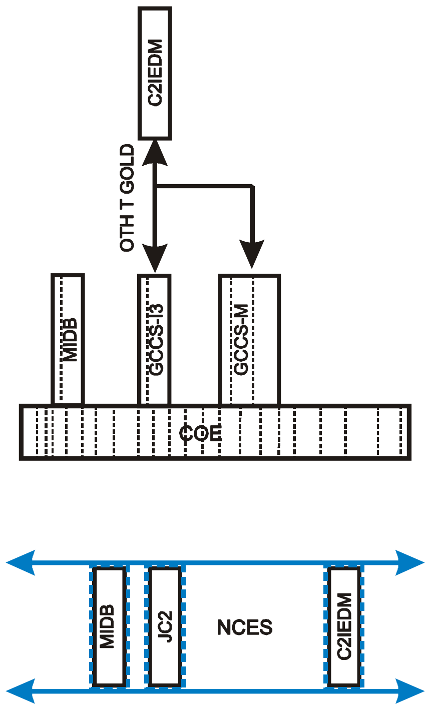

Figure 4. The upper panel shows the COE as a set of COE-component segments (indicated by dashed lines). Applications that operate within the COE (e.g., GCCS-M) contain mission-application segments. C2IEDM would be linked to the GCCS systems by a mapping that utilizes OTH-T-GOLD messages.
The lower panel shows NCES as a broad environment into which applications are placed. Wrappers that allow the application to communicate with the NCES are shown as blue dashed lines.

The central objectives of XTCF are to establish and leverage a data management framework that allows the easy integration and use of data sources that support a common operational picture, and to support the use of the GCCS-M communication and tactical data exchange. The XTCF vision is a common enterprise to which sensor data, correlation engines, applications and databases are connected (Figure 5). The Phase 3 software development plan [28] calls for the incorporation of MIDB into the XTCF. Although the integration of the C2IEDM is not currently described in the development plan, there is no technical reason why C2IEDM could not be incorporated in a similar way.

The second US initiative of relevance to this investigation is the Family of Interoperable Operational Pictures (FIOP) [29]. The FIOP is intended to fuse data available in individual systems, into a common operational and tactical picture. The program has 10 focus areas, including the Situational Awareness Data Interoperability (SADI) and Tactical Data Link (TDL) Integration. The SADI objective [30] is to define a common data exchange for situational awareness. The basis for this data exchange is the C2IEDM. The other focus, the TDL, intends to integrate the Joint Data Network (JDL) with the GCCS FoS. Thus, indirectly the FIOP will contribute to the effort to combine data from C2IEDM and GCCS.

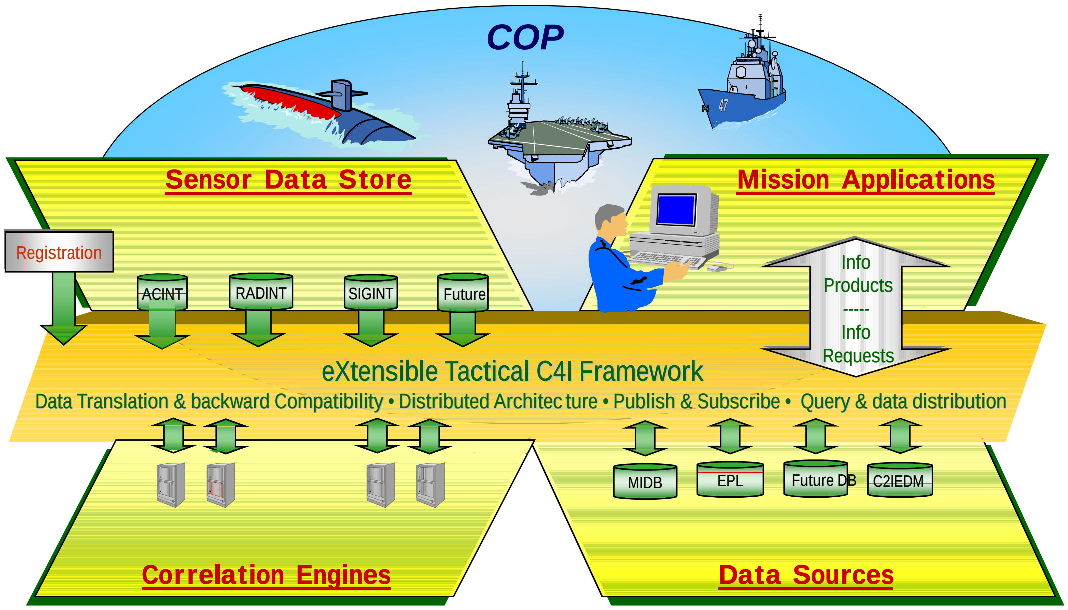

Figure 5. The vision of XTCF. Data sources, such as acoustic intelligence (ACINT), radar intelligence (RADINT), signal intelligence (SIGINT) and other future sensors provide sensor data to the enterprise. The correlation engines and applications utilize the sensor data and those data in other data sources such as the MIDB, the electronic intelligence (ELINT) Parameter Limits (EPL) and other databases such as the C2IEDM. This figure is based on a figure from [27].

5. Concluding Remarks

Considerable effort is being placed on the design of architectures and the development of systems that support interoperability. In many ways, this effort is being fuelled by shrinking resources available to militaries around the world, but also by common goals to protect and serve the citizens of the individual nations.

The commonality of issues faced by national militaries, combined with the collection of similar data types, provides the environment for collaborative sharing of data and information across national systems and services. However, there exists the continual need to rationalize demonstrations of existing technologies with current operational procedures. As well, demonstrations must account for, but not necessarily integrate with, planned or emerging systems that may impact existing procedures.

In the Canadian navy, present research is examining the general topic of Network Enabled Operations. This research is considering numerous subtopics including the integration of data from multiple sources (e.g., either sensors or, nonorganic tactical or combat systems).

The Canadian military research community is moving forward with these investigations, while recognizing both short and long term client needs. Part of the requirements for the Canadian navy is interoperability with the USN and at least a data sharing capacity with other services of the Canadian Forces.

These requirements do result in research and development issues. The issues arise because the USN is firmly committed to GCCS-M and JC2. Alternately, the Canadian army is developing systems in support of the C2IEDM.

This report has outlined an integration path for the Canadian navy. The path provides the continued use of GCCS-M and future JC2, while establishing a data sharing capacity with the army C2IEDM. The integration is possible due in part because GCCS and C2IEDM are compatible systems. Over the short term, the C2IEDM could be mapped to the OTH-T-GOLD structure, thus providing a data stream from the army systems to GCCS-M. In the longer term, the C2IEDM is envisaged as a data source within the NCES.

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List of symbols/abbreviations/acronyms/initialisms

ACINT	Acoustic Intelligence
Adat-P3	Allied Data Publication 3
ALIX	Atlantic Littoral ISR Experiment
API	Application Programming Interface
ARM	Automated Replication Mechanism
ASW	Anti-Submarine Warfare
ATCCIS	Army Tactical Command and Control Information System
C2DB	Command and Control Database
C2IEDM	Command and Control Information Exchange Data Model
C2IS	Command and Control Information Systems
C4I	Command & Control, Communications, Computers and Intelligence
CES	Core Enterprise Services
CF	Canadian Forces
COE	Common Operating Environment
COI	Community-of-Interest
COP	Common Operating Picture
CUP	Common Underwater Picture
DB	Database
DEM	Data Exchange Mechanism
DII	Defense Information Infrastructure
DISA	Defense Information Systems Agency

DND	Department of National Defence (Canada)
DoD	Department of Defense (US)
DRDC	Defence Research and Development Canada
DRP	Document Review Panel
ELINT	Electronic Intelligence
EPL	ELINT Parameter Limits
ESM	Enterprise Service Management
ESMTP	Extended Simple Mail Transfer Protocol
FIOP	Family of Interoperable Operational Pictures
FoS	Family of Systems
GCCS	Global Command and Control System
GCCS-A	GCCS Army
GCCS-I3	GCCS - Integrated Imagery and Intelligence
GCCS-J	GCCS - Joint
GCCS-M	GCCS - Maritime
GCCS-T	GCCS - Top Secret
GIG	Global Information Grid
I&RTS	Integration and Runtime Specification
ICCRTS	International Command and Control Research and Technology Symposium
IR	Information Requirement
IEM	Information Exchange Mechanism
IER	Information Exchange Requirement
ISR	Intelligence, Surveillance and Reconnaissance

ISTAR	Intelligence, Surveillance, Target Acquisition and Reconnaissance
JC2	Joint Command and Control
JC3IEDM	Joint Consultation Command and Control Information Exchange Data Model
JDL	Joint Data Network
LC2IEDM	Land Command and Control Information Exchange Data Model
LFC2IS	Land Forces Command and Control Information System
MEM	Message Exchange Mechanism
MIDB	Modernized Integrated Database
MIP	Multilateral Interoperability Programme
MIST	Maritime Information Sharing Technology
MTF	Message Text Format
MTIDP	MIP Technical Interface Design Plan
NATO	North Atlantic Treaty Organization
NCES	Net Centric Enterprise Services
NCW	Net Centric Warfare
NEOps	Network Enabled Operations
NUWC	Naval Undersea Warfare Center
OCXS	Operational Context Exchange Service
ONR	Office of Naval Research
OTH-T-GOLD	Over-The-Horizon Targeting Gold
RADINT	Radar Intelligence
SADI	Situational Awareness Data Interoperability
SIGINT	Signal Intelligence

SQL	Structured Query Language
TD	Technology Demonstration
TDL	Tactical Data Link
TMS	Tactical Management System
US	Unites States
USD	Unites States Dollars
USMTF	US Message Text Format
USN	United States Navy
XML	eXtensible Markup Language
XSLT	eXtensible Stylesheet Language Transformation
XTCF	eXtensible Tactical C4I Framework

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The Canadian Forces is currently investigating numerous technologies that support data exchange. Within the Canadian navy, the Global Command and Control System (GCCS) represents an important system in use on all Canadian Frigates. The GCCS is also used extensively throughout the United States navy (USN) and thus the Canadian use also provides interoperability with the USN. Within the Canadian army, considerable resources and intellectual effort has been dedicated to the development of a semantics basis, shared among the NATO allies, called the Command and Control Information Exchange Data Model (C2IEDM). Since the Canadian forces also seek interoperability among its own services (air, navy and land), information exchange between the GCCS and C2IEDM-based systems like the Land Forces Command and Control Information System (LFC2IS) needs to be explored. Furthermore, this information exchange must take place in such a way to minimize semantic loss between systems. This report outlines both GCCS and C2IEDM and suggests a way forward for information exchange while maintaining semantic integrity. In the short term, it is suggested that C2IEDM be mapped to the messaging structure used by GCCS. In the long term, it would be advisable to have C2IEDM as an integrated ontological basis for the next generation of the supporting environment, namely the Net Centric Enterprise Services (NCES).

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Land Command and Control Information Exchange Data Model
LC2IEDM
Command and Control Information Exchange Data Model
C2IEDM
Global Command and Control System
GCCS
Defense Information Infrastructure Common Operating Environment
DII COE
Net-Centric Enterprise Services
NCES
Modernized Integrated Database
MIDB

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